WALLACE (Wm CLAY)

The structure of the eye

+++

THE

STRUCTURE OF THE EYE,

WITH REFERENCE TO

NATURAL THEOLOGY.

BY WILLIAM CLAY WALLACE,

Oculist to the New-York Institution for the Blind, and to the Orphan Asylum; late Physician to the Northern Dispensary, &c.

NEW-YORK:

WILEY & LONG, 161 BROADWAY.

1836.

Osborn & Buckingham, Printers,
88 William-street.

TO

WILLIAM MACKENZIE, ESQ.

Lecturer on the Diseases of the Eye in the University of Glasgow.

My Dear Sir,

When I was Surgeon's Assistant at the Glasgow Eye Infirmary, under you and the late Dr. Monteath, I had many proofs of your friendship; as a small acknowledgment of which, and of your attention since, I dedicate this to you.

Respectfully, yours,

W. C. WALLACE.

553 *Pearl-street, New-York,*
1st February, 1836.

PREFACE.

THE eye affords a wide and interesting field for observation. The ingenuity of the contrivance, and the adaptation of the means to the end that is to be accomplished, are exhibited in its structure, which is always varied to suit the wants of the possessor. It has been almost always brought forward by writers on Natural Theology, as a convincing proof that such an instrument could only be formed by a wise Contriver.

Owing to the difficulty of examining such a delicate structure, the nature and use of some of its parts are disputed. Independently of these, the evidences on which all are agreed are quite sufficient for the argument.

It is probable that the present attempt will be followed by a similar view of the other organs of sense as soon as opportunity will allow.

CLASSIFICATION

OF

STRUCTURES OF THE EYE.

---

1. Refractors of Light.	*Aqueous Humor, Crystalline Lens, Vitreous humor.*
2. Receiver " "	*Retina.*
3. Reflector " "	*Tapetum.* [Exists only in nocturnal animals.]
4. Absorber " "	*Choroid.*
5. Regulator " "	*Iris.*
6. Regulators to Distances.	*Falciform Membrane, Muscle of the Crystalline Lens, Marsupium, Ciliary Circle.*
7. Case.	*Cornea, Sclerotica.*
8. Movers.	*Muscles.*
9. Protectors and Cleansers.	*Socket, Eyebrow, Eyelids, Eyelashes, Apparatus for the Tears.*

LIST OF CUTS.

THE

STRUCTURE OF THE EYE.

THERE are few who have not been pleased with the representations of a camera obscura. The light reflected from objects, after passing through a magnifying glass into a small chamber, with darkened walls and roof, and falling upon a sheet of paper at a certain distance from the glass, forms a beautiful picture upon the paper. The representation of the scene before the glass is so true to nature, that artists often avail themselves of this method of making a correct landscape. The eye is just such an instrument, consisting of several magnifiers, placed in a dark chamber for a similar purpose. The light reflected from objects before it, passes through the magnifiers and forms a picture at the back of the eye, where the rays thus collected strike upon the fibres of the optic nerve, and vision is the consequence.

In describing this interesting organ, we shall commence with the outer case—we shall then examine the layers or coats beneath it—the magnifiers—the means by which the picture of objects at different distances is formed only on the expansion of the optic nerve—the coloured circle round the pupil called the iris—the muscles which give motion to the eyeball; and, lastly, the apparatus for furnishing and carrying away the tears. Unless otherwise expressed, the description refers to the eye of man.

Sclerotica.—More than four fifths of the outer case of the eye consist of a strong tough membrane, called, from its hardness, the sclerotica. It forms the white of the eye, which, by its firmness, keeps the parts in situation while it receives the attachments of all the muscles that give motion to the eyeball.

Cornea.—The remainder of the outer case, called the cornea, has the appearance of a small watch-glass, which is fitted to the sclerotica like a glass to the watch-case. As it is the only transparent part of the case, it may be called the window of the eye. The skin covering the cornea resembles the cuticle, in being renewed after accidental removal, and in chemical composition; yet it differs in being perfectly transparent. Both consist of albumen, which freely transmits the light when formed over the cornea, but becomes opaque where transparency is not required. The cornea is lined by a membrane of another nature, which, by its power of resisting corrosion, preserves the eye from destruction when it is almost penetrated by an ulcer.

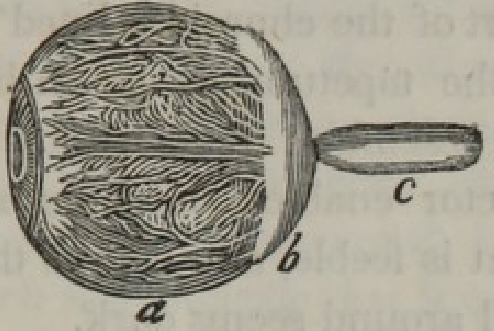


Fig. 1.—*a* Choroid; *b* Sclerotica; *c* Optic Nerve.

Choroid.—Immediately under the sclerotica there is another coat or case, called the choroid, which consists of a number of very fine blood-vessels, spread out like the branches of a weeping willow. It prepares the dark paint which is deposited round the inside of the eye for the purpose of absorbing unnecessary light, and thus making the image formed on the expansion of the nerve to be more distinct. The divisions and bendings of the blood-vessels which pass to the eye, and their arrangement in the choroid, prevent an irregular flow of blood; for if the beats of the heart were continued to the eye, the sight would be disturbed by every pulsation. In the cat and the dog, animals which watch their prey for a long time, the division, subdivision, and reunion of the blood-vessels, before entering the eye, are very remarkable. The beats of the heart are not felt after these divisions, the blood flows in a regular manner, and the eye does not lose its object. (Fig. 14, page 32.)

Tapetum.—In animals that obtain their food at night, a part of the choroid is lined* by a membrane called the tapetum, which in brilliancy of color almost resembles polished metal. This concave reflector enables those animals to see when the light is feeble, and causes their eyes to shine when all around seems dark.

Membrane of Mondini.—Over the inner surface of the tapetum and choroid there is a magnificent net-work, called, from its discoverer, the membrane of Mondini, which can be seen only with a microscope. It resembles a huntsman's net, with meshes so fine that not a globule of the dark paint which lines the choroid can pass through it to sully the delicate nerve.

Retina.—The optic nerve enters the cases through an opening placed a little towards the inner side of the centre of the eye, from which it is spread out to form the retina. During life the retina is transparent, but after death it becomes opaque, and so soft that the layers of which it is composed cannot be separated without being artificially hardened. The internal layer is a fine membrane covered with extremely minute blood-vessels, which branch out like the veins in a leaf, and afford nourishment to the parts under which they ramify. Exterior to this the fibres of the nerve, which in some animals resemble the finest floss silk, radiate from the opening above-

---

* Mackenzie's MS. Lectures, 1825.

mentioned in the most minute division. (Fig. 2, *a*, and Fig. 14.) Over the fibres there is a layer of pulp retained in its place by one of the finest membranes in the body, called, from the anatomist who first discovered it, the coat of Jacob, which is so delicate that it can scarcely be recognised without examining the eye under water.

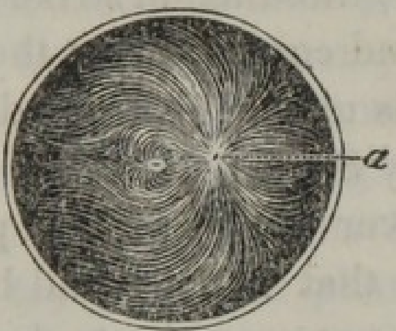


Fig. 2.—FIBRES OF RETINA.
a Entrance of Optic Nerve.

There is an opening* on the centre of the retina in man, and in some reptiles† whose vision is remarkably acute, which has not been found to exist in other animals. I have ascertained that the ends of some of the fibres of the optic nerve meet round this opening as in the figure. The probable use of this arrangement of the fibres, is to enable the eye to see very minute objects ; for as sensation is most acute at the extremities of nerves, the impression from a minute object, received on the ends of the fibres thus collected, will

* The foramen of Soemmering. † Knox.

be more powerful than elsewhere, just as a stroke on the end of a wire causes a greater vibration than on the middle. There is manifest design in the structure of the vascular membrane of the retina, for no large blood-vessel approaches this peculiarly sensible spot.

The rays of light, after passing through the magnifiers, fall upon the delicate fibres of the expanded nerve; these again strike upon the pulp behind them, and communicate the sensation to the brain. This may be illustrated by an experiment related by Sir Charles Bell: "Close the eyelids and cover them with a piece of black cloth or paper that has a small hole in it, and place this hole, not opposite to the pupil, but to the white of the eye; direct a beam of light upon the hole: a person will see this light in its true direction." In this experiment the light falls upon two parts of the retina; the same or a greater impulse is given to the fibres first struck, but we see only one circle of light. When the light passes through the retina in the first instance, it forces the fibres against the vascular membrane without producing an impression, but when it strikes upon their concave surface, and impels them against the pulp, the light is seen in the true direction.*

* See my remarks on the Retina in Silliman's Journal, vol. xxviii.

The impression of light remains on the retina some time after it is received. When a stick, burning at one end, is turned rapidly round, the whole of the circle through which it passes becomes luminous. At every change of place, the fibres of the expanded nerve are struck by the light from the burning wood before the previous impression is removed, and the appearance of a continued circle is thus produced. If the impression of light did not remain some time on the retina, the sight would be unsteady, for objects would disappear while winking.

The duration of impressions has been studied in making a toy called the phantascope. Upon a circular card figures are painted, gradually changing from one attitude to another, which appear in active motion when the card is turned round; because the impression from the figures at one extreme of attitude, is gradually lost before the card is turned round to the other extreme.

The fibres of the retina seem to resemble the other parts of the body in becoming enlarged after violent exercise. If, when the eye is directed steadily forward, we move a lighted candle up and down on one side of the line of vision, an image of the blood-vessels, resembling a withered tree, will soon appear as if displayed on a screen. The fibres being unusually exercised by the light dashing upon them in surges, become swelled and press against the blood-vessels, which appear very much magnified from the proportion of the retina they occupy, compared with the space taken up by an ordinary image. When the cause is discontinued, the fibres soon recover their usual dimensions.

The fibres of the retina are subject to exhaustion by a continued play of light against them. When with one eye we look intently at a narrow slip of paper, on a green cloth, a large portion of the paper alternately disappears and comes into view, that part only being permanently seen, the light from which falls on the centre of the retina. The exhaustion is very conspicuous when the light is feeble, as the disappearance and reappearance of an object at which we look steadily are then peculiarly remarkable. Sir David Brewster is of opinion, that many fancied apparitions must have owed their origin to this cause, when fear or curiosity called forth all the powers of observation.

It has been already remarked, that the optic nerve does not enter the eye at the centre, but a little toward the inner side. (Fig. 3, *g*.) Had it entered at the focus of the lenses, vision would have been indistinct, for it is insensible at the part where it expands to form the retina. In order to be convinced of this, place two wafers on a wall about a foot apart, and with the right eye directed to the one on the left, shut the other. When the observer is near, both objects are seen, but by withdrawing three or four feet, one of them becomes invisible, because the light from it strikes upon the entrance of the nerve. By withdrawing farther, the light from the wafer falls on another part of the retina, and the object again appears.*

As the nerve where it enters each eye is absolutely blind, we should expect to see two dark spots on every landscape; but as has been observed by Sir David Brewster, "The Divine Artificer has not left his work thus imperfect. Though the base of the optic nerve is insensible to light that falls directly upon it; yet it has been made susceptible of receiving luminous impressions from the parts which surround it, and the consequence of this is, that when the wafer disappears, the spot which it occupied, in place of being black, has always the same colour as the ground upon which the wafer is laid."

It has been found by experiment, that of all animal substances free of air, the worst conductors of heat are fat and jelly. In order to retain the animal heat, and thus keep the retina in a proper condition for receiving impressions, the socket is filled with fat at every interstice not occupied by other important parts. The eyes of fishes are much exposed, the head being the part that first passes through the cold water. In some of the perch kind, the very eyeball is more than

* Mariotte.

a third filled with fat, closely packed behind the expanded nerve, between the sclerotica and choroid. (Fig. 5.) There is a cavity between the same coats in the halibut, filled with a gelatinous fluid, (Fig. 6, *b*,) which I at first thought was a reservoir of liquor, that, by external pressure, might be forced to the fore part of the eye to make it more convex; but by a closer examination of its structure, a much superior provision for accommodating it to distances may be observed. In the shark, the jelly is encased in parallel tubes, which surround the front of the socket and pour it out on the skin, while at the back of the eye there is the usual deposition of fat.

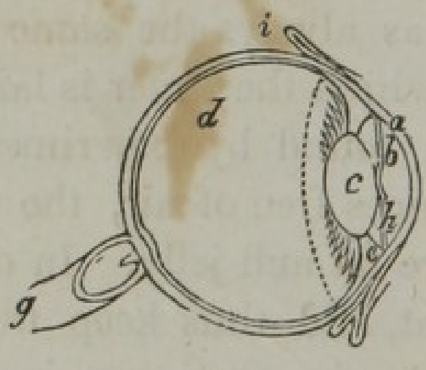


Fig. 3.—SECTION OF THE EYE.

a Cornea; *b* Aqueous Humor; *c* Crystalline Lens; *d* Vitreous Humor; *e* Ciliary Processes; *g* Optic Nerve; *h* Iris; *i* Fold of Conjunctiva.

Vitreous Humor.—About three fourths of the hollow globe of the eye is filled with the vitreous humor, (Fig. 3. *d*,) which is a watery fluid contained in transparent cells that prevent the contents of the eye from running out when wounded; the fluid of the opened cells only, then escapes, and the form of the eye is preserved. The membrane surrounding the vitreous humor and forming the cells, is called the hyaloid membrane.

*The Crystalline Lens** (Fig. 3, *c*,) consists of a series of coats placed under each other, which are again composed of fibres that gradually increase in compactness as they approach the centre. It has the appearance of a magnifying glass, placed in a pit made to receive it at the front of the vitreous humor. With all the light of modern knowledge, no artist can manufacture a lens so perfect as that possessed by the meanest animal. The structure of the crystalline lens has been imitated by making use of glasses of different degrees of density, and the result has been, that optical instruments have been much improved, but still the imitation is far from perfect. "Could this be in the eye, without purpose, that suggested to the optician the only means of attaining that purpose."†

According to the laws of light, the rays pro-

---

* Sir David Brewster has lately ascertained that the fibres of the crystalline lens of the cod are locked together by a kind of teeth resembling those of rack-work. He found the number of teeth in each fibre to be 12,500. As the lens contains about 5,000,000 fibres, the number of these minute teeth will amount to 62,500,000,000.

† Paley.

ceeding from objects in water require a denser and more powerful lens to collect them at a short focus, than those coming from objects in air. Conformably to these laws the crystalline lenses of fishes are either almost, or altogether, spheres which are very hard at the centre. The omniscient Creator has thus provided for the necessities of fishes, by supplying them with lenses suited to the element in which they live.*

The crystalline lens is contained in a transparent case called its capsule, which attaches it to the vitreous humor. In man and quadrupeds the margin of the case is extended over the front of the vitreous humor, leaving an unattached part between them called the canal of Petit. When the margin of the case is separated from the vitreous humor by blowing air between them, the crystalline lens advances, while the air thus made to encircle the lens resembles a plaited ring. The margin of the case retains the crystalline lens in a situation proper for the direction of the light, and seems to allow it to be moved backward and forward to regulate its focus.

Aqueous Humor.—The remainder of the hol-

* When examining the eye of a certain species of hawk, I noticed that the crystalline lens was a plano-convex, and the cornea unusually prominent. There is a probability, that as the posterior surface of the lens was flat, the image received through such a projecting cornea was prevented from being formed before the retina.

low globe is filled with a clear fluid, named the aqueous humor, which distends the cornea and permits the colored circle round the pupil, called the *iris*, to have free motion. If the fluid were contained in cells like the vitreous humor, the enlargement or diminution of the pupil would be interrupted.

The aqueous humor kept in the fore part of the eye by the cornea, the crystalline lens in its case, and the vitreous humor in its cells, are the parts essential to the eye as an optical instrument. They bend the rays of light in such a manner, that an image of the bodies from which they are reflected is formed on the expansion of the optic nerve at their focus. But as the image of objects at a distance is formed at a point different from that at which the image of those at hand is formed, there must be some provision for accommodating the eye to different distances.

THE MEANS BY WHICH THE EYE IS ACCOMMODATED TO DISTANCES IN DIFFERENT ANIMALS.

When examining the eyes of fishes, I observed a small white body, shaped like a bee's wing, attached to the iris and crystalline lens, connected with the membrane forming the cells of the vitreous humor. From the perfect similarity of this body to the white muscular substance of fishes, and from its attachments, I was convinced of its nature and office. In various fishes the muscle had different forms, as a bee's wing, a triangle, a hammer, or a bell;* and as it was always present unless its place was supplied by a sythe-shaped membrane,† or when the crystalline lens was not a sphere by membranes at the front of the vitreous humor called the ciliary processes, and as there was always one of these three provisions, and only one, I concluded that the membrane, the muscle, and the ciliary processes, were different structures for performing the same function.

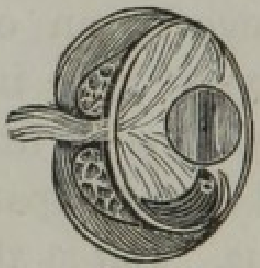


Fig. 4.—*a* Falciform Membrane.

Falciform Membrane.—In the herring, the mackerel, and various other fishes, there is a membrane, which, passing through a division in the lower part of the retina, is attached to the iris and crystalline lens. By the contraction of the part of the membrane behind the crystalline lens, the lens will be drawn from the cornea, while the former will be drawn toward the latter by the contraction of the part attached to the iris.

* Haller. † Cuvier.

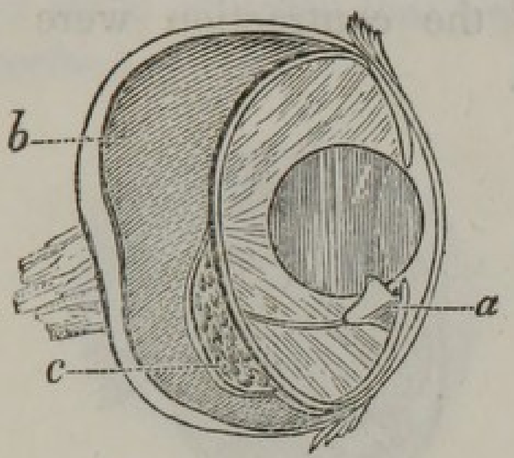


Fig. 5.—EYE OF STRIPED BASS.

a Muscle of the Crystalline Lens; *b* Fat; *c* Choroid-Gland; *l* Crystalline Lens.

Muscle of the Crystalline Lens.—In the striped bass, and probably in all the perch kind, there is a white triangular muscle attached to the sheath of a nerve which enters at the back of the eye, and runs along a division at the lower part of the retina. One of the angles of the muscle is fixed to the crystalline lens, and another, after passing through a loop at the back of the iris, is inserted into the vitreous humor. When the part of the muscle which passes through the loop contracts, the crystalline lens will be drawn toward the cornea. When the part which is between the crystalline lens and the cord to which the muscle is attached contracts, the lens will be drawn in an opposite direction. By the passing of the muscle through the loop, or pully, at the back of the iris, the lens may be brought nearer the cornea than if the contraction were made in a straight line.

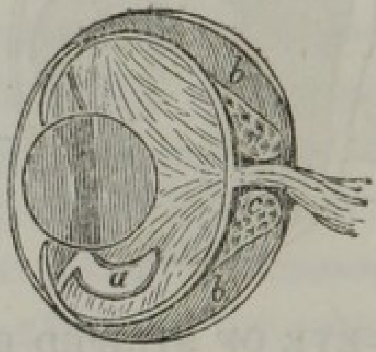


Fig. 6.—EYE OF HALIBUT.

a Muscle of the Crystalline Lens; *b* Gelatinous Fluid; *c* Choroid Gland.

In the halibut the muscle is larger than in the striped bass, and of a different shape; but there is no loop behind the iris. The vitreous humor being the fixed point, the contraction of the part marked *a* will draw back the crystalline lens, while the contraction of the part between the lens and the iris will draw it toward the cornea.

As the crystalline lens, in most fishes, is a sphere, the rolling motion caused by the action of the muscle upon it at one point, will make no change in the direction of the rays; but motion produced by action at only one point, will not succeed in adjusting a lens of another form, without turning it away from the object to be viewed. The fishes in which the crystalline lens is not a sphere, have a provision at the front of the vitreous humor, called the ciliary circle, the structure of which, in some animals that live in air, will soon be described.

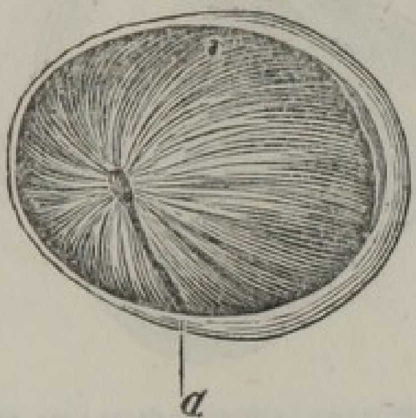


Fig. 7.—RETINA OF HALIBUT.
a Division of the Retina.

As far as has been ascertained, the division in the lower part of the retina exists only in the fishes in which the crystalline lens is a sphere. It is always on one side of the line of vision and allows passage for the falciform membrane, or the nerve to which the muscle of the crystalline lens is attached. Those parts endowed with a high degree of vitality, have a large supply of nerves to convey the impulses of the will, which seem to be instantaneously obeyed. When it is the desire of the animal to adjust the eye to an object, according to the distance, the part of the membrane or muscle before or behind its point of attachment to the crystalline lens contracts, until a perfect image of the object is formed on the retina, and thus communicated to the brain. Had the retina been entire, the sheath of the nerve having, by the action of the muscle, a tendency to become straight, would rise upon and thus disturb it.

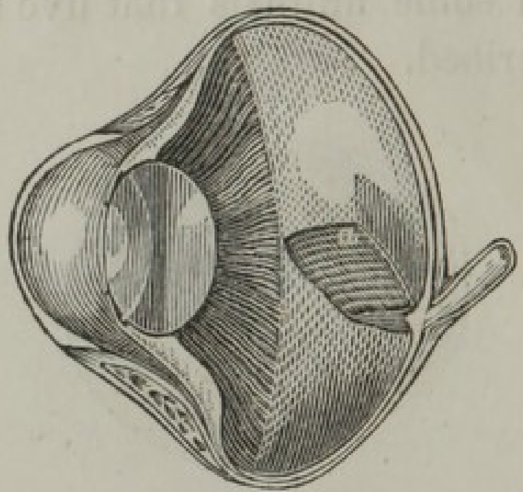


Fig. 8.—EYE OF EAGLE.

a Marsupium.

Marsupium.—In birds, a membrane resembling a little fan, called the marsupium, arises at the back of the eye, where it passes through a division in the retina, and is then inserted into the vitreous humor, not far from the foremost or inner edge of the crystalline lens, out of the way of direct vision. The eyes of birds are directed to each side to afford the wide field of vision which their necessities require; yet when this membrane contracts, it will alter the position of the crystalline lens by drawing back the inner edge, and thus enable the bird to look straight forward. From numerous dissections, I believe it to be established that the marsupium becomes smaller, in proportion as the direction of the eyes become parallel. By drawing back the crystalline lens, this membrane will assist in accommodating the eyes of birds to distances; but as the direction of the lens would be then changed, the organs cannot be regularly adjusted in this manner.

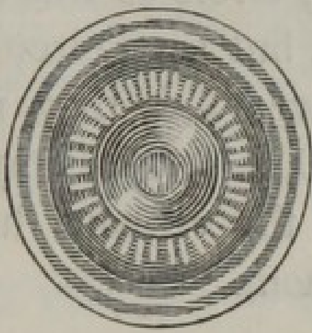


Fig. 9.—CILIARY CIRCLE.

Ciliary Circle.—At the border of the choroid there is a ring called the ciliary circle, which is attached by white ligamentous matter to the sclerotica. Muscular fibres, arranged in a radiated form, may be seen beneath the white attaching matter, when it is carefully separated from the ciliary circle of an ox.* Muscular fibres may also

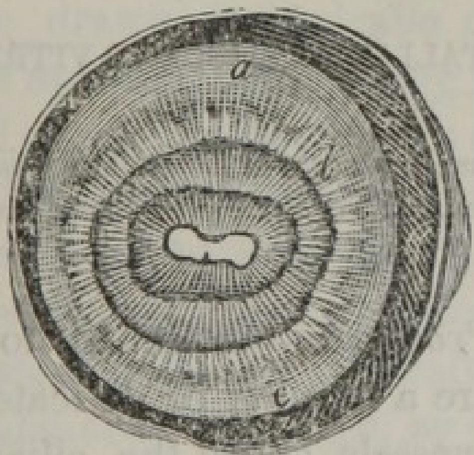


Fig. 10.—CILIARY CIRCLE OF SHEEP.

a Upper Ciliary Muscle; *b* Ciliary Processes; *c* Lower Ciliar Muscle.

* See an interesting paper on the muscularity of the cilia ligament, by Dr. Knox, Ed. Phil. Trans, vol. x.

be observed by brushing away the dark paint that lines the ciliary circle of a sheep. On the upper half of the ciliary circle of this animal, the fibres are not radiated, but semi-circular, (Fig. 10, *a*,) while on the lower half they resemble those of the ox. (Fig. 10, *b*.) The impression of these fibres is left on the vitreous humor when it is separated from them.

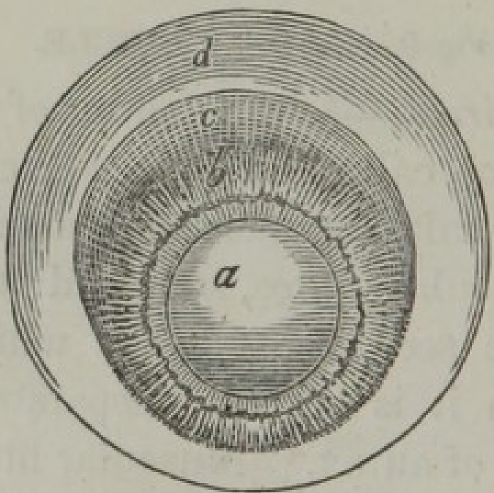


Fig. 11.—CRYSTALLINE LENS, AND VITREOUS HUMOR OF SHEEP.

a Crystalline Lens; *b* Margin of Crystalline Case over the Canal of Petit; *c* Impressions of the Upper Ciliary Muscle; *d* Vitreous Humor.

Ciliary Processes.—Attached to the ciliary circle there are a number of delicate membranes full of blood-vessels, called the ciliary processes, which are so arranged round the crystalline lens that it has the appearance of a sun-flower.

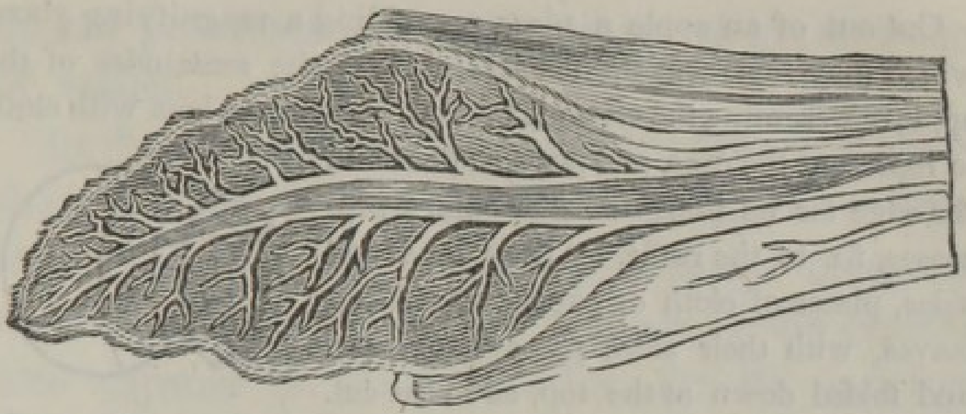
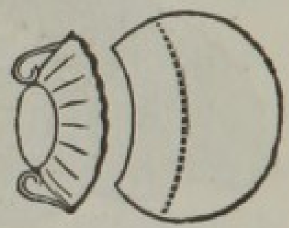


Fig. 12.—CILIARY PROCESS OF OX, MAGNIFIED.

Each process resembles a leaf, which is triangular when folded, the edges being received into the plaits of the crystalline case, where it is extended over the front of the vitreous humor, and so strongly attached that they can be separated only by rupture. When the muscular fibres contract, an additional quantity of blood will be collected in the processes, which will then be elongated, and the case containing the crystalline lens will be drawn toward the cornea. The action of the muscular fibres being discontinued, the distended blood-vessels will then contract upon themselves, the processes will become shorter, and the case containing the lens will be drawn back. If an eye be frozen, and cut across, it may be easily understood how the crystalline lens may be made to advance or go back, by the extension or contraction of the ciliary processes.* (See Fig. 3, *e*, Ciliary Processes.)

* In carnivorous quadrupeds the processes are triangular plates.

Cut out of an apple a piece resembling a magnifying glass, which may represent the crystalline lens, the remainder of the apple representing the vitreous humor. Cover the lens with cloth to represent the case, and put a ruffle round the edge for its margin. For ciliary processes, fix to the ruffle, by their tops and sides, pieces of cloth or paper, resembling leaves, with their sides pressed together, and folded down at the top, as in the cut.



Put the lens into its socket, and fix the edge of the ruffle to the vitreous humor at the dotted line. Unfold the leaves, and the ruffle with the lens attached to it will be drawn forward; close them again and it will be drawn back.

The muscular fibres described have not been distinctly ascertained in man, owing to the difficulty of obtaining an eye in a condition proper to be examined. Being so conspicuous in quadrupeds, it is inferred that they exist in man.

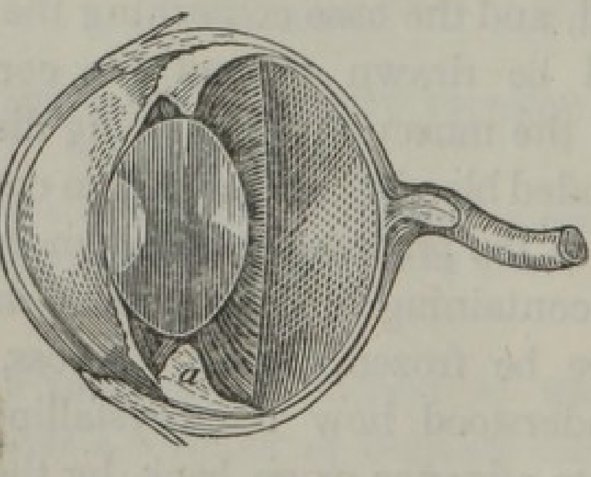


Fig. 13.—EYE OF LYNX.

a Ciliary Processes.

The lynx has long been considered the most quick sighted of animals. From the size of the ciliary processes it should possess a great range of vision.

In the sheep, the ciliary muscle is broader above than it is below; the fibres take a different direction, that they may more effectually compress the ciliary veins, and the margin of the crystalline capsule is there broader, for the apparent purpose of removing the image from the bright reflector to a part that is darker. In all animals examined, the retina ceases where the ciliary circle begins, lest there should be any interference with the impressions of light. It is divided in fishes apparently for no other purpose than avoiding the motions of the membrane, or the cord which is attached to the muscle of the crystalline lens.

By the eighty processes arranged round its circumference, the crystalline lens is drawn backward and forward, and even a little obliquely, like a magnifying glass with eighty strings at its edge, pulling it and adjusting it to fit the distance and the direction of the object.

The experiments of Audubon show that the turkey buzzard does not discover carrion by smell; yet, though very remote, it will find its prey when a carcass is exposed. The observations of others on birds, prove that they see at a great distance. Their ciliary circle is of great breadth and made stiff by plates of bone wedged into each other. A strong fixture is thus afforded to the processes when they require unusual exertion.

When we look from one object to another, we are conscious of an effort, and that some time is necessary for distinct vision, to allow the processes to be extended or contracted, and the lens adjusted. The winding direction of the carotid artery before it gives off the blood-vessels of the eye, and their bendings, and re-unions before reaching the processes, prevent the adjustment being disturbed by the beats of the heart.

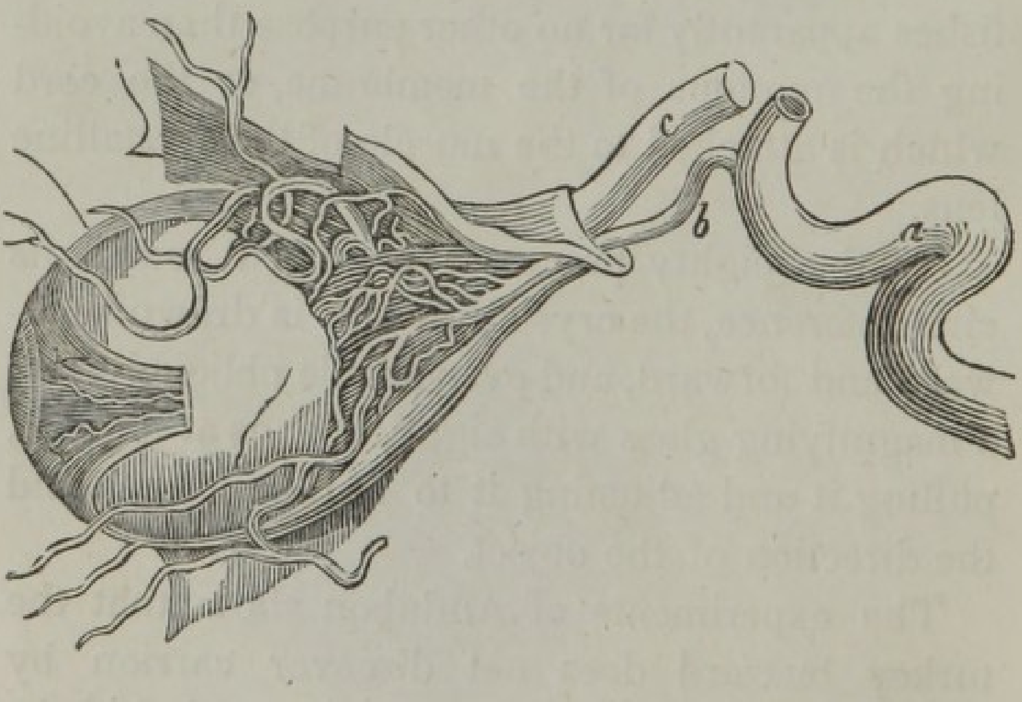


Fig. 14.—BLOOD-VESSELS OF THE EYE.

a Carotid artery; *b* Ophthalmic artery; *c* Optic nerve.

The theory of the motion of the crystalline lens was advanced by Kepler,* the celebrated

* Porterfield.

astronomer and mathematician. It has fallen into disrepute, but it may be proved by any one who will minutely examine the eye of a sheep. The ciliary circle has not been made in vain. The membranous processes, and the muscular fibres accompanying them, must have a use, and that use, it is evident, is for acting on the crystalline lens. In those fishes whose crystalline lens is a sphere, there are neither ciliary fibres nor processes; the lens is moved by a single membrane or muscle, attached at only one point, which is all that is necessary for its adjustment. The beautiful and complicated ciliary arrangement does not exist, because it is not required.

Iris.—Suspended from the union of the ciliary circle with the outer case or sclerotica, and immersed in the aqueous humor, is the circle which gives color to the eye, and which, by becoming larger or smaller, regulates the admission of light into the dark chamber. (Fig. 21, *h*, *Iris.*) The opening in the centre, called the pupil, is black, owing to the paint on the inside of the choroid. The strings of the expanded nerve are very tender: their use would be destroyed by too much light, for we know that persons have become blind by sudden exposure to the direct rays of the sun. Northern travellers protect their eyes from the glare of the snow, by wearing spectacles that admit only a very small portion of light through a hole in the centre. In a feeble light, unless the pupil enlarged to admit more rays, the nerve would not be sufficiently affected, and if it did not become small when the light is strong, the nerve would be injured.

As has been remarked, the eyes of those animals that obtain their food at night, are furnished with a reflector almost as bright as polished metal, which prevents the total loss of light by absorption, but reflects it again, and thus produces sufficient agitation of the fibres of the retina, when the light is feeble. In a strong light, a retina, accompanied by a reflector, would be more violently exercised than without such an accompaniment. Accordingly we find, that to exclude unnecessary light, the iris in nocturnal animals is capable of great contraction. Of the fishes I have examined, the skate is the only one furnished with a reflector: to protect the retina, which is in consequence unusually sensible, there is a curtain at the upper part of the pupil, having the appearance of a hand, the fingers of which may be so expanded that the light may be altogether excluded or admitted, only through very small chinks.

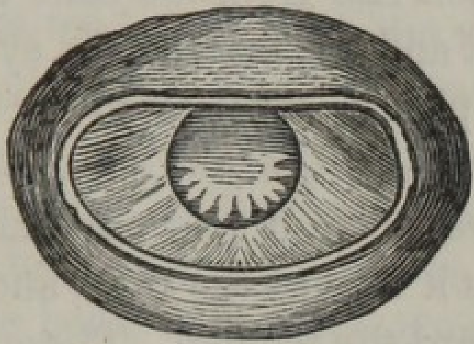


Fig. 15.—EYE OF SKATE.

During sleep the pupil is contracted and turned upward, and the eyelid drawn down; three provisions are thus adopted to exclude the light and allow the nervous fibres repose.*

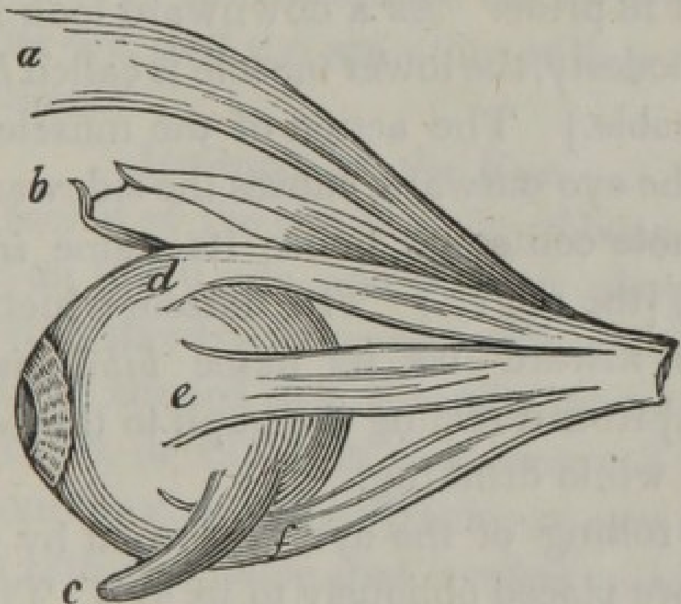


Fig. 16.—MUSCLES OF EYEBALL.

a Muscle that lifts the upper eyelid; *b* Upper oblique Muscle passing through its pulley; *c* Lower oblique; *d* Upper straight Muscle; *f* Lower straight Muscle; *e* Outer straight Muscle, parallel to the Inner straight Muscle on the other side.

The motions of the eye are effected by six

* Bell.

muscles, which rise from the bone at the bottom of the socket and are fixed to the eyeball. Four of these are placed opposite to each other, and are called the *straight muscles*, one of which turns the eye upward and another downward; another turns it toward the nose, and the remaining one toward the temple. These muscles are named according to their actions. 'The upward turning of the eye' being expressive of devotion, the upper muscle is sometimes called *pius*, [the pious,] from producing this effect: it is also called *superbus*, [the proud,] because, with a peculiar disposition of the muscles of the face, it is partially elevated in pride. As a downward look is peculiar to modesty, the lower muscle is called *humilis*, [the humble.] The action of the muscle which draws the eye outward, causes the sideward looks that denote contempt, hence its name *indignabundus*, [the angry.] The muscle which draws the eye inward has its name *bibitorius*, [the drinker,] from directing the pupil to the bottom of the cup while drinking.

The rolling of the eye is caused by muscles which are placed obliquely to its axis. The lower oblique commences near the nose, and passes under the eye to the outer part of the case, where it is fixed. (Fig. 16, *c*.) The upper oblique rises from the bottom of the socket, and ends in a cord, which passes through a ring, and then turns back to be fixed to the outside of the eyeball. The passing of the tendon through the ring resembles the placing of a rope over a pully to move an object in the required direction, while an additional contrivance for keeping it moist, makes it move easily like machinery that is oiled.* The upper oblique being expressive of tender passions, is called the pathetic.† "By its six muscles," observes Dr. Barclay, "the eye, like the needle of the mariner's compass, pointing to the pole, preserves the same relative position with regard to its object, whether the object be in motion or at rest; and hence it is, that instead of the eye moving in its socket we sometimes see the socket moving round the eye, and the eye quite still performing its functions."

Defences of the Eye.

The socket of the eye is made of bone that defends it on every side, and projects above like a roof, having its edge furnished with the eyebrow, which is so shaped that it conducts the sweat of the forehead, or the rain that may fall upon it, away from the eye. The eyelids are covered with fine soft skin, so pliable that it offers no resistance to their motions. A small gristle, placed like pasteboard in each edge, retains them in form and keeps

* Dalrymple.

† As there are only nine pair of nerves which rise from the brain, it is somewhat remarkable, that the small muscles, said to express love and anger, should each have a pair devoted exclusively to themselves.

them nicely fitted to the eye. The eyelashes, which are placed in irregular rows on the outer edges of the eyelids, exclude dust and unnecessary light. When applied to each other they form an interlacement which keeps the opening secure. (Fig. 21, *g*, roots of eyelashes.)

Meibomian Glands.—On the inside of the eyelids there are a number of little glands, (Fig. 20, *c*,) which prepare an oily fluid that passes through a number of holes at the edge of each eyelid, for keeping them from sticking together, and preventing the tears from running upon the cheek, as water does not pass readily over a vessel, the edge of which is smeared with oil.

Conjunctiva.—The eyelids are lined by a soft moist membrane, which, when they are moved, passes over the transparent window, and keeps it clean and polished. It is turned from the eyelids to cover the white of the eye, and thus forms a fold, which prevents motes from getting behind the eyeball, and destroying the organ, by producing inflammation. (Fig. 3, *i.*) The nerve which animates the lachrymal gland is spread out on this membrane, and there is such a sympathy between them that the moment a particle of dust irritates the sensible conjunctiva, there is a gush of tears to wash it away.

Muscles of Eyelids.—The upper eyelid is opened by a muscle which rises at the bottom of the socket and is fixed into the gristle. It resembles the other muscles of the body in being occasionally palsied, and then the sufferer is unable to open the eye. "With much compassion," says a religious philosopher, "as well as astonishment at the goodness of our loving Creator, have I considered the sad state of a gentleman, who, as to the rest, was in pretty good health, but only wanted the use of these two little muscles that serve to lift up the eyelids, and so had almost lost the use of his sight, being forced, as long as the defect lasted, to lift up his eyelids with his own hands."

The eyelids are shut by a muscle that surrounds them, the fibres of which draw them together without wrinkling, because they are kept firm by the gristle. It has been remarked, that when we close the eyelids the pupil is turned upward: if we place a finger over one eye, and wink with the other, the eye will be felt to roll on each motion of the lid. In a person who cannot shut the eye in consequence of palsy of the muscle, or the contraction produced by a burn, we can see the transparent window raised beneath the upper eyelid, and its surface wiped clear at the usual time of winking.

The eyelids of the chameleon are drawn to a circle, which is capable of contracting to a small aperture opposite the pupil, and they move with the eyeball, so that the glistening of the iris is not exposed. Without eyelids to correspond with its habits of concealment, its colour changing with surrounding objects, and its slow and cautious motion would pass for nothing, if the insects upon which it feeds perceived the brightness of its eye; but like the leaves around it, without even the eye exposed, it approaches its prey with so little appearance of life or motion, that the insect is not aware of the presence of an enemy before it is secured.

As the leaps of frogs cannot be always well guided, their eyes would be subject to injury, if they were not covered by transparent eyelids.

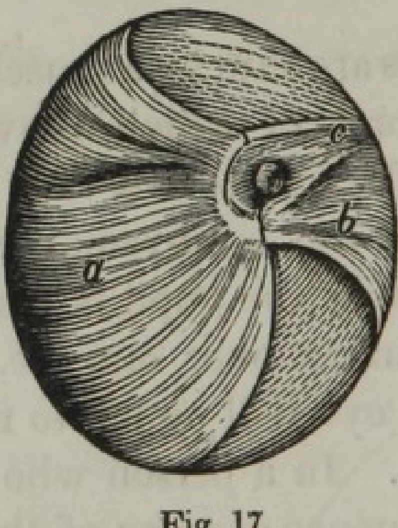


Fig. 17.

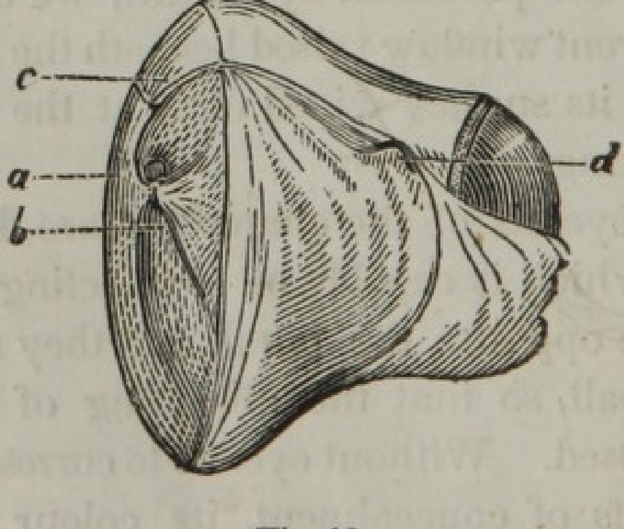


Fig. 18.

Figs. 17 and 18.—MUSCLES OF THIRD EYELID OF OWL.

a The Square Muscle through the edge of which the Tendon *c*, of the Pyramidal Muscle *b*, passes and plays over the pulley *d*.

Third Eyelid.—The eyes of birds are much exposed during their rapid movements among the branches of trees. To suit their necessities they have a third eyelid, which, when drawn over the eye, is an effectual protection to the organ by its toughness, and by its partial transparency vision is not altogether obscured. It is moved by two flat muscles, that, having no room elsewhere, are closely applied to the back of the eyeball. One of the edges of the broader muscle resembles a string case, through which passes the tendon or cord of the other muscle, that is fixed to the membrane. The owl has a small hook projecting from the circle of bone which surrounds the cornea. When the muscles act they pull the cord over this hook, and draw the membrane across the eye, as we would hoist the sail of a ship. No other contrivance in the same room could cover so much surface with the same rapidity.

The eyes of quadrupeds are not defended by a projecting brow like that of man, but are much exposed from their direction and size. They have a third eyelid therefore, called the *haw*, which in some respects resembles the corresponding membrane in birds. A gland on the internal surface prepares a gummy fluid, which it sweeps across the eye to entangle the dust that falls upon it, and to keep the window moist and transparent.

Fig. 20.—EYE OF RHINOCEROS.

In the rhinoceros this gland is of enormous size when compared with that in other animals. This animal is said to plough the ground with its horn, and throw earth and dust on its enemies, by way of defence; the eye is consequently much exposed and requires unusual protection.*

The eyes of fishes being bathed and kept transparent by the fluid in which they live, have no occasion for eyelids, yet the shark, which is obliged to fight, has a scaly covering like a coat of mail, which he can draw over the eye to protect it when injury is threatened.

---

* For the eye of the rhinoceros which died at the Zoological Institute, I am indebted to my friends Drs. Dixon, Doane and Drake, of this city.

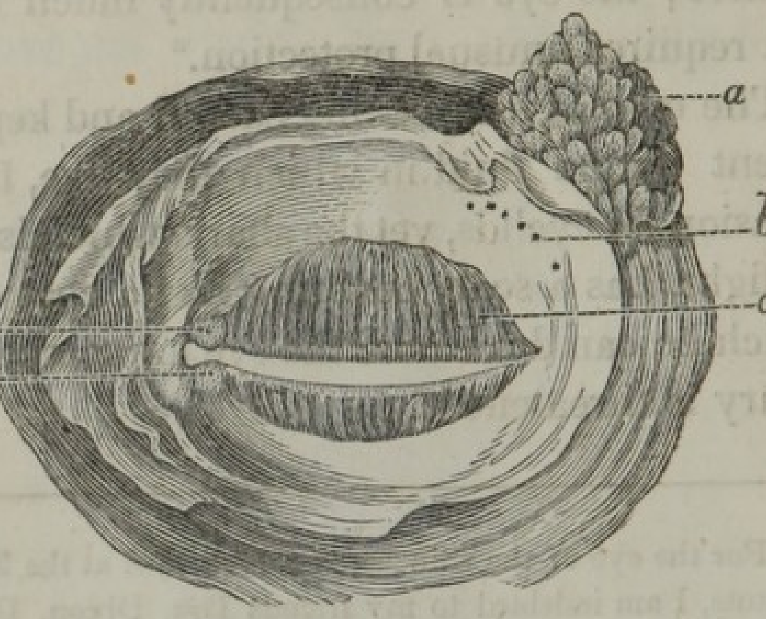


Fig. 20.

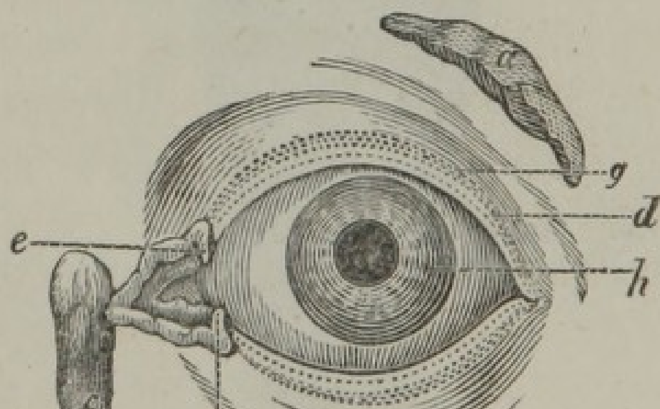


Fig. 21.

Figs. 20 and 21.—APPARATUS FOR THE TEARS.

a The Gland that prepares the Tears; *b* The Passages by which they are poured out on the inside of the eyelid; *c* The Meibomian Glands, which prepare the fluid for preventing their running over on the cheek; *d* The openings of the Meibomian Glands; *e* The Points which take up the Tears; *f* The Channel through which they pass to the Nose; *g* The Roots of the Eyelashes; *h* The Iris.

The gland for preparing the tears is about the size of an almond, and sunk into a hollow of the bone at the upper part of the socket, to be out of the way of the motions of the eye. The fluid which it prepares passes to the inside of the upper eyelid by seven pipes, so small that they will not admit a hair; it is prevented from running over the edge of the eyelids by the oily fluid of the meibomian glands, and is collected at the inner corner of the eye, from which, unless too abundant, it is conveyed away by the action of a muscle* that enlarges the size of the tear bag, (Fig. 21, *f*,) and pumps into it the collected tears through two little pipes, the openings of which, at the inner corner of each eyelid, are kept in situation by a red substance, made elastic by fine hairs. From the tear bag they pass to the nostril, and are evaporated by the current of air which is always passing over it during the process of breathing. "Can any pipe or outlet," says Dr. Paley, "be more mechanical than this is. It is easily perceived that the eye must want moisture, but could the want of the eye generate the gland that produces the tear, or bore the hole by which it is discharged. A hole through" bones.

Numerous nerves which endow the eye with sensation and motion, connect the different parts together, and produce that union of function on which the perfection of vision depends, for the

* The muscle of Horner.

organ becomes defective when any one part is incapable of its office.

In the eye, we find an instrument made perfect for the purpose, with the utmost economy of material. As tears would be of no use to the inhabitants of the deep, no organs are provided for them; but where they are required there is a gland for preparing them, and a channel for carrying them away. When the crystalline lens may be adjusted by the pulling of a single string, a single string is all that we find; but when action at only one point would alter the direction of the light, the requisite strings are liberally supplied. According to the danger to which the organ is exposed there are suitable provisions for defence, but in no instance are they found where they are not absolutely required. Wisdom, power, and goodness, are manifest in the whole structure. The bountiful Creator has provided an organ suited to the wants of His creatures, and with consummate knowledge He has varied it according to the demand.

When the most exquisite work of man is examined with a microscope, the artist is ashamed of the coarseness of his production; but no microscope is sufficiently powerful to exhibit the minute structure of the eye of an elephant or a rhinoceros, far less of a wren or an animalcule.

In the eye of man there is marked care. It is protected by a projecting brow, and placed in such a situation that he can see before him, beneath him, around him, and above him. Its expressions add much to social intercourse, and enable him to explain by a look the thoughts of his heart. But it is by the reason with which he is endowed that his organs excel those of every other creature. When all around is dark, he can make artificial light. By the aid of instruments which he has formed, his sight surpasses that of the lynx or the eagle, and when it is dimmed by age, he can restore its distinctness. By the telescope he discovers that there are no bounds to the vastness of the creation, while the microscope exhibits that its minuteness is unlimited.

The more we pry into the works of the Almighty, the more do we witness the design of an intelligent contriver. We see with what exactness one organ alone is made to correspond with the little, we know, of the laws of optics, chemistry, and mechanics. A Creator there must be who is perfect in every science, and in every art.

What is the composition of this masterpiece of design and fine workmanship? The eye is made of the commonest materials, water, a little charcoal, some air, and a few salts—all ingredients of the dust of the ground.

What is nature? Is it chance? Could chance put a rope over a pulley and place it where required? Could chance make a telescope with glasses to correspond, or fit them into a case in which they could be regulated according to the distance? Above all, could chance make the eye? Could chance prepare its magnifiers, so clear and transparent, from substances, the solid part of which is almost altogether charcoal? Could chance, from the same brittle, porous material, make the fibres of the case so tough that the fingers cannot pull it asunder, or weave them so closely together as to contain water? Could chance spin the fibres of the nerve so fine, that their minuteness has not been ascertained by the microscope, or spread them out at the proper distance behind the magnifiers? Could chance make the crystalline lens of a fish suited to the element in which it lives, or prepare an apparatus to regulate it? Could chance make the iris a measurer of light? Could chance give the eye so many muscles to direct it, or make the string of the upper oblique to pass through a pulley, and then to go back, and be fixed at the part of the case proper for rolling the eye in the direction which is wanted? Could chance lodge the gland which prepares the tears in a hollow of the bone, to be out of the way of the motions of the eye, or make the little holes which pour out the matter that keeps them from running on the cheek, or prepare the passages which convey them away? The answer must be—No.

Of all the creation man alone has been permitted to witness the magnitude, the minuteness, and the design which the Creator has been pleased to exhibit. Surely it is not in vain that he has been endowed with knowledge to recognise Him in His works.

NOTES.

Page 10.—It is often asserted that the conjunctiva is reflected over the cornea. That it does not cover the cornea may be proved by dipping an eye into a solution of corrosive sublimate, cautiously plunging it into boiling water, and then separating the anterior membrane from the cornea, and the conjunctiva which it overlaps. Porterfield, in the opinion of the author, has given a correct account of the membrane, though unsupported by proof.

Page 13.—The fibres of the retina may be exhibited by separating them with a hair pencil in an eye that has been steeped in alcohol, and the exposed retina hardened by a solution of corrosive sublimate.

Page 34.—Anatomists are not agreed about the structure of the iris. To deny that there are circular fibres in some animals, would be to deny the evidence of the senses; but are these fibres muscular? They do not dissolve by putrefaction, but remain like firm ligaments at the edge of the membrane. In the most moveable *irides* the radiated fibres do not approach the lesser circle, which is the principal place of motion. As they are far more numerous than the circular fibres, we would expect, with Bichat, that they would be more liable to contract by the stimulus of light, and cause the pupil to be expanded. In the ox, but more particularly in the calf, there are a number of fibres on the back of the iris, at its greater circumference, the nature of which cannot be investigated on account of the pigment, but they are so situated that by their contraction the blood will be collected in the membrane. I am inclined to believe that these are the fibres which are paralyzed by belladonna, and that the contraction of the vessels upon themselves cause the pupil to be dilated. If the iris contracted by the radiated fibres, we would expect to see the membrane contracting at the middle, and not at the very edge, as may be finely witnessed in the eye of a hawk, each fold being drawn up behind the other in a similar manner to the lifting of a curtain. In the white rabbit the lesser circle of the iris is a fine membrane, almost as fine as the ciliary processes. When the pupil in this animal becomes small, the fibres seen on the front of the iris dash toward the centre like the pulling out of the cases of a telescope, and when it expands they return like the pushing of them back. Microscopical observations on this animal might lead to correct conclusions on the subject.